

# Cross-pollination in bioenergy

Innovation networks between the bioenergy and biotechnology in Denmark

**Piirainen, Kalle A.**

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## 2B. ENERGY, INNOVATION AND ENVIRONMENT

# Cross-pollination in bioenergy: Innovation networks between the bioenergy and biotechnology in Denmark

Kalle Piirainen
(Technical University of Denmark – DTU)
kalpii@dtu.dk

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1. The originality of the proposal and its relevance for the conference theme and for the track theme (if chosen)
This paper explores the interactions between technological innovation systems and the development of those interactions. The empirical context is the Danish bioenergy innovation system and its interaction with biotechnology innovation system. The significance of the research is twofold. In the academic context it yields more insights about the influence of interactions between innovation systems, enabling better understanding of their development. In the practical context the findings illuminate the particular dynamics between bioenergy and biotech, in its part paving the way for supporting further development of bioenergy and industrial biotechnology.
It is well-known that bioenergy in Denmark is often closely connected to the agricultural sector. In terms of renewable energy production and use in Denmark, biomass is by far the most important source (e.g. in 2013 out of a total consumption of 187PJ, 134 PJ [Petajoule] was generated out of biomass as opposed to 40 PJ from wind power). Overall Denmark satisfies a total of approximately 24% of gross energy consumption by renewable sources. (Danish Energy Agency 2014). The Danish biomass and bioenergy system has been previously studied by several authors (e.g. Raven & Gregersen 2007). Beside the relatively strong renewable energy industry, Denmark has in relative terms exceptionally strong bio-medical industry. For example, Denmark is among top countries in clinical trials per capita, RDI and publishing on biomedical area (Invest in Denmark 2014). The connections between the bioenergy sector and biotech industry can be expected to be of high importance for the future competiveness of new bioenergy solutions also on other markets than in Denmark. The examples can appear in different sub areas of the bioenergy, e.g., biomass for heat and power plants, urban-waste use, biogas from agricultural waste products, and biofuels for transport. In this study we focus on investigating the connections between these innovation systems.

2. The clarity and explicitness of the research aim(s) and question(s)
There is need of more systematic insight and better understanding of innovation activities and networks between biotech actors and bioenergy actors, and transfer of technology between industries, especially in Denmark. The research questions for this paper are:
• What is the structure and evolutions of networks between bioenergy and biotech industries?
• What has been the role of actors and their contribution to innovation from the collaboration between the sectors?

3. The clarity and explicitness of the definitions of the most central concepts used
For the purposes of the identification of relevant technologies and the following analysis, ‘bioenergy’ in the context of this paper refers to the use of biomass from various industrial and household side-flows, residues, and wastes or virgin biomass from forestry and agriculture to produce energy by direct combustion or through conversion to solid, gaseous or liquid fuels for power plants, vehicles, or households. The processes are varied depending on the aimed end product or use. The main conversion technologies can be split to direct thermal (McKendry 2002; Küçük & Demirbaş 1997; Demirbaş 2001), thermochemical conversion (Demirbaş 2001; McKendry 2002), biochemical (Saxena et al. 2009), and chemical conversion (Boz et al. 2009; Saka & Kusdiana 2001; Zwart & Boerrigter 2005; van Steen & Claeys 2008), and as newer entrants photo-biological conversion (Turner et al. 2008), and electrochemical conversion (Logan & Rabaey 2012).
As for the theoretical concepts, the most central is the concept of ‘innovation system’, as in “the set of institutions whose interactions determine the innovative performance of ... national firms” (Nelson 1993, p.4).

The behavior of the system arises as the various actors interact through networks within boundaries set by the framework conditions, infrastructure and cultures (e.g. Nelson 1993; Carlsson & Stankiewicz 1991).

4. The outline of the theoretical frameworks to be used (if relevant)
The current literature on technical innovation systems (TIS) has had a strong focus on describing the development of a particular TIS, in many cases focusing on renewable energy, especially wind power (Alkemade et al. 2007; Kern et al. 2015; Verhees et al. 2015) or bioenergy and biomass (Hellsmark & Jacobsson 2009; Negro et al. 2008; Verbong et al. 2008; Geels & Raven 2006; Wirth & Markard 2011; Furtado et al. 2011; Kivimaa & Mickwitz 2011). The research focus has been to a large extent on tracing the functions of innovation systems and their contribution to the development, and identifying the 'motors of change' (Hekkert et al. 2007), 'motors of innovation' (Negro & Hekkert 2012) and growth or 'cumulative causation' (Suurs & Hekkert 2009) i.e. beneficial feedback loops between the actors of the TIS and the functions (Negro & Hekkert 2012; Suurs & Hekkert 2009; Jacobsson & Bergek 2011).
This focus has provided a substantial body of knowledge on the inner workings of TISs. However it is pointed out that TISs do not work in isolation and the dynamics of the surrounding context as well as other interconnected TISs have their own influence to the dynamics through connected knowledge flows, and shared input-output relationships (Jacobsson & Bergek 2011; Bergek et al. 2015). Thus the focus on examining the dynamics interactions between the innovation systems and their effect to growth.

5. The description of the empirical materials to be used (if relevant)
The data used to map the networks include the database for publicly funded research, development and innovation. This database includes information on collaborative RDI projects and in particularly description of technologies and consortia, that will be used to gauge knowledge development and transfer between the two industries under investigation. Further data will be joint publications from identified actors, as well as secondary data including published academic and other literature or archival data on bioenergy innovation that will enable gauging the functions of these innovation systems.

6. The clarity and explicitness in the description of the methodologies applied
The research approach is built on the 'Manual for analysts' of TISs (Hekkert et al. 2011). The analysis proceeds from describing the structure of and networks within these TISs, assessing the functions, and analyzing the interplay between the functions and the TIS development. The analyses include mapping of the existing networks and relevant institutions. The network analysis is based on analysis of the RDI programs as well as bibliometric analysis of relevant publications. Particular attention will be paid to technological trajectories and their convergence.

7. Expected outcomes (scientific and policy advances) likely to be achieved
The contribution of this research specifically is exploration of interconnectedness between technical innovation systems and the interplay between TISs in their context. This provides further understanding of the development dynamics of TISs and the roles of the functions. Particular findings include description of knowledge networks and actors, their interaction, and knowledge flows, as well as effect to innovation activities. These findings will give grounds for analysis of effect of networking within and between TISs towards innovation. The analysis in turn enables design of more effective policy instruments for 'system building' and supporting thriving innovation (eco-) systems.

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